Hence p equals the weight of a column of mercury 1 square centimeter in cross section and 1/30,156,820,271 centimeter, or, say $1/(3\times10^9)$ millimeter, high.

That is, a local electrification of the outer atmosphere sufficient to produce a potential difference between it and the earth, having an equal charge of opposite sign, of 1 volt per centimeter difference in level would increase the height of the mercurial barometer about $1/(3\times10^9)$ millimeter.

If, however, the outer atmosphere were charged to this extent over all the earth, each square centimeter of it (regarded as a charged surface) would be repelled radially outward by the rest of the charge on the shell with the force F given, as is well known, by the equation

$$F=4\pi\rho^2.$$

Hence, from (1), per square centimeter of the charged surface,

$$F=2P.$$

That is, if the upper air is charged to the extent supposed, all around the earth, the mercurial barometer will stand *lower* by the same amount it would stand *higher* in response to an equally dense local charge, namely, in the present case, by $1/(3\times10^9)$ millimeter.

But, as an extreme case, let the charge be local, as first assumed, and let the potential difference with change of elevation be 30,000 volts per centimeter, a value far in excess of any observed except occasionally, perhaps, during the passage of a thunderstorm. With this extreme local electrification the barometer would be raised only about 3/10 millimeter.

Obviously, therefore, no appreciable portion of those considerable changes in atmospheric pressure, giving differences in the readings of the barometer of, say, 2 to 3 centimeters, characteristic of the passage of cyclones and anticyclones, can logically be attributed to variations in the electrification of the upper air, whether at the times of auroras or at any other time. Hence, it seems extremely improbable that either cyclones or anticyclones are ever produced by changes in the electrification of the outer atmosphere.

551.54 (520)

PRESSURE MAPS AT THREE KILOMETERS IN JAPAN.

By S. FUJIWHARA.

[Central Meteorological Observatory, Tokyo, Japan, Sept. 19, 1921.]

NOTE.—A paper by S. Nakamura in the February, 1921, number of the *Journal of the Meteorological Society of Japan* entitled "Upper air currents and volcanic ashes from Asama" contains a reference to the practice, in Japan, of drawing maps of pressure at the 3-kilometer level. Dr. S. Fujiwhara, who devised the method, was asked if he would not kindly explain it for the benefit of those in this country who might be interested. The following interesting account of the method has been received in response to this request.—EDITOR.

Our primary object in drawing the upper isobars was to learn their forms and to get the direction and the relative intensity of the upper wind. We noticed first that the error for the pressure at any level lower than 4,000 meters that arises from the inaccurate estimation of the intermediate temperature is not serious, and also that what we want most is the general trend of the upper isobars, but not the absolute values of the pressure at the level concerned. For the general trend, the errors themselves do not produce much disturbance, but the differences, which are by no means so great, of errors for pairs of adjacent stations might come into effect. For example, suppose the errors for all stations lie within the limits of 8.5 and 11.5 mm. Then the mean error of 10 mm., being common to all, makes no disturbance in the general trend of the isobars at that level, which is actually affected by errors of ±1.5 mm., which, for practical purposes, can be overlooked.

We began to draw upper isobars for our daily weather service in March, 1919, following the principle of Ferrel and Bigelow; by applying several artifices of our own and also that of Köppen, we arrived at an idea that the most useful isobars of the upper layers are those between 3,000 meters and 4,000 meters, so far as the vicinity of the Japanese Empire is concerned. We found by experience also that for the weather service quickness and simplicity of the process are preferable to precision.

The simplest way to draw isobars for the 3,000-meter level from the data at the earth's surface is as follows:

(1) Take the figures of pressure in millimeters of mercury, reduced to sea level and to the freezing point of water and add them to the figures of air temperature in centigrade at the same station. For example:

Reduced barometric reading	752.4 mm.
Reduced air temperature	24.1 °C.
Sum	776.5

(2) Enter the figures thus obtained into a chart and draw isopleths just as isobars. These lines are approximate isobars at the level of 3,000 meters.

By this method we get the general form and trend of the isobars at 3,000 meters, from which we can get also the idea of the direction of the wind there prevailing and also its relative intensity; because, as Sir Napier Shaw has already shown, the direction of the upper wind is nearly always tangential to the isobars at that level. From the distance separating consecutive isobars we can guess the relative intensity of the wind. We do not know, however, the absolute value of the pressure for each isobar, because the figures obtained above are only relative ones. As already has been shown by Mr. S. Takayama, we can get the approximate value of the pressure in millimeters by dividing the figures by 2.

Why do such figures give the relative values of pressure at the level of 3,000 meters? The reason is simple. We can easily see that the middle value of pressure difference corresponding to the difference of 1 mm. at mean sea-level is nearly 0.67 mm. For the range of pressure variation at mean sea-level, 730 to 780 mm., the deviation of the actual value of the pressure difference from the above mean value of 0.67 mm. is less than 0.03 mm., which is negligible for practical work. The pressure difference at 3,000 meters corresponding to a difference of 1° C. in the mean temperature of the air column from sea level to 3,000 meters is also nearly 0.67 mm., and the deviation from this value according to the temperature variation is also not great. This accidental coincidence of the pressure difference at the level of 3,000 meters due to pressure and temperature variation at the earth's surface enables us to make the above artifice.

*   *   *   *   *

Expressed mathematically,

$p_3-P_3=(0.67+\alpha)\epsilon+(0.67+\beta)\theta_m$ in which, p_3 is the current pressure at 3 kilometers, P_3 the mean pressure at that level, ϵ the difference between current and mean pressure at sea-level, θ_m the difference between current and mean average temperature of the air column, and α and β two small quantities representing variations from 0.67 mm., as a result of the range of pressure and temperature, respectively. As shown above, $\alpha\epsilon$ and $\beta\theta_m$ are negligibly small, so that,

$$
\begin{aligned}
p_3 - P_3 &= 0.67\ (\epsilon + \theta_m) \\
&= 0.67\ (p_0 - P_0 + t_m - T_m) \\
&= 0.67\ (p_0 + t_m) - 0.67\ (P_0 + T_m) \\
&= 0.67\ (p_0 + t_m) - \text{a constant.}
\end{aligned}
$$

This holds if the lapse rate is uniform. When the lapse rate is not uniform, we ought to make some allowance for it so that

$$p_3 - P_3 = 0.67\ (p_0 + t_m + \tau) - \text{a constant.}$$

For our purpose τ can be obtained by rough estimation. From the results of the actual observation of the upper air temperature we can make a table for τ corresponding to various circumstances; e. g., fair weather, rainy, near the surface of discontinuity, morning, evening, summer and winter, continental, oceanic, etc.

We compared the isobars thus constructed with those obtained by the ordinary methods and found good agreement between them. Dr. Nakamura's short memoir also shows the availability of the method.

DISCUSSION.

By C. LE ROY MEISINGER.

It may occasion some surprise to discover that it is really possible to add pressure to temperature at the surface and obtain pressure in the free air. But, as Dr. Fujiwhara says, this is being done every day in Japan. Since the making of pressure maps in the free air is of considerable interest in connection with certain barometry problems in the United States it will be instructive to point out one or two features which may be pertinent to the application of a similar device here.

The level at which a certain increment of pressure at sea-level produces the same effect as a certain increment of temperature applied to the mean temperature of the air column, is given, neglecting the effect of vapor pressure, by the equation:

$$h = 18400 \log \left(\frac{B_0 + \Delta B_0}{B_0}\right) \frac{[1 + \alpha(2\theta + \Delta\theta) + \alpha^2\theta(\theta + \Delta\theta)]}{\alpha\Delta\theta},$$

in which B_0 is the pressure at sea-level, α is 0.00367, the coefficient of gas expansion, θ the mean temperature of the air column, ΔB_0 and $\Delta\theta$ the increments of pressure and temperature, respectively. If, for example, we substitute for B_0, 760 mm., and for θ, 0° C., and for ΔB_0 and $\Delta\theta$, 1 mm. and 1° C., respectively, we obtain 2,818 meters as the value of h. This is the situation assumed by Dr. Fujiwhara; and, since only the horizontal pressure gradients are of interest, it is accurate enough to designate the reduction level as 3,000 meters. If millibars were used instead of millimeters, the level at which pressure and temperature effects are equal is 2,164 meters. Hence, if the Japanese map were drawn in millibars, the reduction level should be approximately 2,000 meters. In this manner any convenient combination of values of ΔB_0 and $\Delta\theta$ may be used. In the ordinary use of the hyspometric equation it is easy to lose sight of this interesting relation.

Would this method be useful in the United States? The answer lies in the difference between the behavior of the small term τ which Dr. Fujiwhara has inserted in his last equation. If the lapse rate is uniform, a difference of 1° C. at the surface would mean a change of 1° C. in the mean temperature of the air column; and, under such conditions, one would be justified in adding temperature to pressure. But when the lapse rate is not uniform, and that is most of the time, it is necessary to correct our sum by the value τ, which depends upon a number of factors, as shown by Dr. Fujiwhara.

Japan is a small country relative to the United States. Its area is about that of the State of California. Moreover, it is surrounded by extensive ocean areas, and its climate is consequently maritime. It is natural that temperature changes at the surface and aloft should not depart markedly from those characteristic of the ocean. In other words, the free-air temperature distribution should be steady and uniform, and thus should tend to diminish irregularities of τ, consequently rendering the method more reliable.

But in the United States, the situation is quite different. The extensive continental area produces strong seasonal variations between inland and coastal regions; and the elevation differences between the east and west, the extremely variable nature of the surface covering, and topographic irregularities, result in a complex of temperature conditions that would make it difficult, if not impossible, to tabulate, as they do in Japan, the probable variation from the uniform lapse rate.

Again, the pressure conditions are more regular above Japan than above the United States. Our country lies in the path of storms moving in from the North Pacific and the result is a pressure situation quite variable from one part of the country to another owing to its great extent. This, combined with the irregular temperature effects mentioned above, would probably effectively militate against the use of such an artifice in this country.